

RECONSIDERATION OF NEW ZEALAND BIOGEOGRAPHICAL PROBLEMS, WITH SPECIAL REFERENCE TO THE MESOZOIC.

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INTRODUCTION

New evidence of sea-floor spreading, and new interpretations of the tectonic history of Australia and the southwest Pacific region have been published recently^{1,4}. These provide stimulating background against which New Zealand biogeographical problems and Mesozoic history can be reappraised.

It is pertinent to briefly recapitulate views on the origins and composition of the New Zealand fauna and flora held prior to publication of the recent geophysical data. New Zealand had been regarded as an island archipelago with a rather mobile geological history, far enough removed from the nearest large land-mass to be considered oceanic, but with a large enough surface area for a significant degree of evolution and speciation to have occurred at least to the generic level, in virtual isolation^{5,6}. There are some archaic endemic elements such as the *Dinornithiformes*, and of course the *Apterygiformes*^{5,7}, but most precursors of present taxa probably originated outside New Zealand. The assembly of taxa was considered to have taken place over a time scale that allowed for migration over possible Palaeozoic and early Mesozoic connections to other land-masses, and via early to mid-Tertiary archipelagic links. Trans-oceanic dispersal by air and water from neighbouring continental areas and islands was thought to have played quite an important role at all times in New Zealand's history in assembly of the disharmonic fauna and flora of the archipelago^{6,8}.

We can now ask if the new geophysical data invalidate these conclusions, or require that they be modified in some way. Recent literature includes a paper by Jardine and McKenzie, who stated⁹, with reference to interpretation of marine magnetic anomalies and reconstructions of drift within the Pacific¹⁰, and Indian Oceans¹¹, "The date... (of the reconstructions)... can also be obtained with an error of less than one million years. It is therefore no longer profitable for biologists to speculate about the past arrangement of land masses." The writer has an ingrained scepticism concerning the arrival of "millenia" in science and prefers to regard the new data with some caution. Dogmatic statements of that type frequently have to be retracted later. After all, quite radical conclusions based on interpretations of palaeomagnetic data have been strongly modified or overthrown before (see Darlington, with regard to work carried out the late 1950s and early 1960s¹²). Nevertheless for the present the writer is content to examine the several reconstruction variants published, and re-interpret New Zealand biogeography within the limits of the model that is most in accord with available data.

The Australian geologists and geophysicists contributing new analyses of palaeomagnetic data and tectonic history of the area have not considered biogeographical implications of their studies as yet. The writer regards this as very healthy since it tends to eliminate an important source of bias.

NEW EVIDENCE ON THE GEOLOGICAL HISTORY OF THE WESTERN SOUTH PACIFIC

While the differences between the reconstructions recently proposed for the tectonic evolution of the western South Pacific are very minor in the global context of continental drift, they carry very considerable implications for interpretations of New Zealand biogeography. The most recent reconstructions at time of writing are those of Griffiths³, and Griffiths and Varne⁴ who have re-examined the relationships of the Ross-Adelaide Orogenic Belt, the Tasman Orogenic Zone and the New Zealand Geosynclinal Zone in respect of tectonic plate theory, and have published the morphological reconstruction of the western South Pacific margin of Gondwanaland resulting from their calculations. A timetable for its disruption is based on marine magnetic profiling data of Pitman *et al.*¹⁰ and other workers^{1,12}. Formation of the Pacific — Antarctic Ridge seems to have occurred about 80 million years or so ago (Upper Cretaceous)¹⁰, with a marked change in direction of sea-floor spreading taking place about 30 million years later (Eocene)^{1,11}. Christoffel and Ross¹⁴ reported that studies of the magnetic anomalies of the Endeavour Fracture Zone implied sinistral rotation of the Campbell Plateau, the southern part of the "New Zealand Plateau" of Brodie¹⁵, during the Eocene. Sea-floor spreading between Antarctica and Australia began about 50 million years ago^{1,12}.

Carey¹⁶ postulated sphenochasnic opening of the Tasman Sea without any north-south axial displacement; this is in accord with the model of Griffiths and Varne, who showed that plotting the age of successive marine magnetic anomalies gave an age of about 80 million years for the deep Tasman Basin. This estimate lies within the range of the much less accurate value of 90 ± 40 million years published earlier by Vogt and Conolly¹⁷. Griffiths and Varne are in general agreement with Fleming¹⁸, and Suggate¹⁹, that evidence for slip on the New Zealand alpine fault before the mid-Jurassic is totally lacking. In fact Wellman²⁰ provided evidence that the slippage had occurred no earlier than within Tertiary time.

There are a few points in their arguments with which the writer is not entirely happy. Firstly, Griffiths noted that crust thickness below the Solomon Islands was reported by Officer²¹ to be of the order of 15 km, and that this together with presence of a Cretaceous igneous and metamorphic base²², suggested that the archipelago represented in part a fragment of the continental crust of Gondwanaland adjacent to the Rennell Ridge, at the outer edge of the Papuan Geosyncline. While this may eventually prove to be correct, the writer finds Griffiths' interpretation of the Solomons as part of the Gondwana crust rather unconvincing without further evidence. Coleman²³ goes on to say about Officer's²¹ paper "...a result based on the rather slender seismic evidence then available. The recent gravity work suggests a lower figure (than 15 km)." Griffiths does not cite this statement. Richards *et al.*²⁴, discussed radiometric age determination results for the Solomons, and concluded that the major metamorphic phase occurred between the Cretaceous and Upper Eocene. The geology of fractured island arcs like the Solomons is not satisfactorily understood yet. There is (ambiguous) evidence of some differential slippage of the northern part of the archipelago (the Pacific Province) against the southern part (the Central Province), with major faults on the islands of Choiseul and Santa Ysabel. These data are still quite insufficient for use in interpretation of the general features of the tectonic history of the region to the north of New Caledonia and New Zealand²⁵.

Secondly, the writer also sees a geological problem in the southern part of the region. Wright²⁶ discussed the theory and mechanism of continental drift in the western South Pacific and concluded that New Zealand was once part of Antarctica (note that this simplified statement in his summary is belied by the more complex and likely situation he shows in his fig. 3). This author noted that a serious problem in the theory stemmed from results of age determination of the rocks of West Antarctica by Aronson, using a rubidium-strontium method²⁶, since these showed a high degree of incompatibility with ages of the western New Zealand metasediments published by Gunn²⁶. On the other hand Griffiths cited the Antarctic Map Folio Series²⁷, as well as his own unpublished work in the Nelson

and Fiordland Provinces of New Zealand to show that in both are present "sequences similar in age and variety of deformation style". Neither he, nor Griffiths and Varne, cite the specific papers of Aronson and Gunn mentioned above. Consequently the writer, a non-geologist, is faced with two apparently irreconcilable statements and lacks the evidence or skill to decide them.

Common factors are agreed upon concerning the tectonic history of the western South Pacific even by authors holding quite different views on the mechanisms by which drift has come about. Cullen²⁸ visualized development of the geosynclinal arc between New Caledonia and New Zealand on one hand, of the volcanic Tonga, Kermadec, and Macquarie arcs on the other, as resulting from stages of crustal evolution "promoted by a northeastward orientated system of convection currents that originated to the south of Australia and New Zealand." He concurred with Wright²⁴ that New Zealand was probably once much closer to Antarctica, and that the original southern continuation of the southwest Pacific geosynclinal arc lay "among the folded geosynclinal belts of West Antarctica," described by van Bemmelen²⁹.

The general concept of the "northeastering" of the crustal block containing New Zealand has been reinterpreted by Griffiths³ and Griffiths and Varne⁴ in terms of sea-floor spreading. In 1970 Fleming¹⁸, and Christoffel and Ross¹⁴ postulated sinistral rotation of the Campbell Plateau and the Chatham Rise, the latter through more than 90° with respect to the orientation of New Zealand in the Mesozoic¹⁸. The presently sinuate geosynclinal arc originally had a nearly straight configuration before the Rangitata Orogeny of the Upper Jurassic-Lower Cretaceous. So there is evidence of rifting and differential movement within the "northeastering" New Zealand Plateau block, with the Tasman Sea basin forming as the Campbell Plateau-New Zealand area moved and rotated. Most recently Griffiths and Varne have proposed a model for rifting of the whole region, embracing Australia, New Guinea, Antarctica and New Zealand.

The relationships postulated by Jones², Smith and Hallam³⁰, and Griffiths and Varne⁴, for the apparent relationship between pre-drift Australia and New Zealand differ in one most important respect. The former workers show the southern end of the South Island respectively apposed to the coast of New South Wales (see Jones, fig. 2b), or the Bass Strait region (see Smith and Hallam, fig. 2). Griffiths and Varne show the Lord Howe Rise, Norfolk Ridge and Three Kings Rise between eastern Australia and New Zealand. This point is of great importance for interpretation of biogeographical phenomena in the region. The balance of the evidence in the writer's opinion favours the reconstruction of the latter authors. While the boundaries of the Lord Howe Rise and the Norfolk Ridge are difficult to define because of their relatively gentle marginal slopes, no evidence exists for north-south axial displacement at the northern end of the Tasman Sea. If the Tasman opened as a spheochoasm¹⁶, then in reconstruction of pre-drift configuration it can be closed by rotating the southern end of the Rise back against eastern Australia (see Griffiths and Varne, fig. 3). In addition, studies by Officer²¹, Brodie¹⁵, and most recently Shor *et al.*³¹, all indicate that the Rise and the Ridge contain crust of continental type. Fig. 1 of the present paper shows a reconstruction of the southwest Pacific region of Gondwanaland, based on fig. 3 of Griffiths and Fig. 2 of Griffiths and Varne.

When considering biogeographical phenomena one must bear in mind that continental rifting and drifting are by no means necessarily coincident in time. A few years ago biogeographers (including the writer), tended to treat rifting and continental dispersal rather vaguely as synonymous terms. Now, while rifting of the southern land masses may still be considered as a Jurassic and Lower Cretaceous phenomenon, evidence is accumulating favouring dispersal not reaching major proportions in the western South Pacific region until early Caenozoic. Crustal elements of this part of Gondwanaland apparently remained in apposition even during the very last part of the Mesozoic. The New Zealand biogeographer cannot but wryly recall Wardle³², whose views were hardly given much credence by Fleming and myself^{6,8}, suggesting land connections during the Tertiary to explain the distributions of certain plant genera common to Australia, Tasmania and to New Zealand. Nevertheless although the Lord Howe Rise, the Norfolk Ridge and the Three Kings Rise may represent in part remains of "Tasmantis" land between New Zealand and Australia, this does not necessarily mean that these areas were dry land even during most of the Mesozoic, let alone the Tertiary. The question of the altitude of crustal blocks above sea level may not necessarily be of prime importance

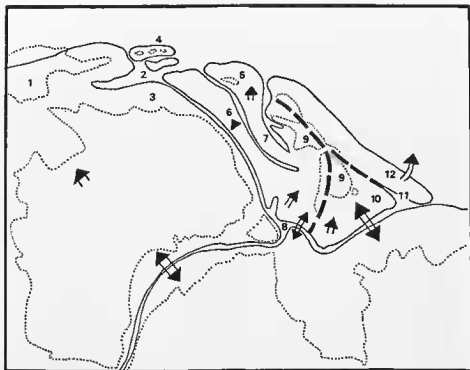


FIG. 1. — Pre-drift configuration of the southwest Pacific region of Gondwanaland, after Griffiths (1971) and Griffiths and Vane (1972). Continuous line shows margins of continental blocks, broken lines the present day land masses, arrows direction of movement and the double arrows sea-floor spreading. 1. New Guinea, 2. Coral Sea, 3. Queensland Plateau, 4. Solomon Islands, 5. New Caledonia, 6. Lord Howe Rise, 7. Norfolk Ridge, 8. Tasman Basin, 9. New Zealand, 10. Campbell Plateau, 11. Bounty Trough, 12. Chatham Rise.

to a geologist reconstructing Gondwanaland, but it is obviously vital for the health and well-being of terrestrial organisms! Even if we accept a greatly revised drift timetable, the land connections discussed by Wardle almost certainly did not exist. In the writer's opinion the balance of evidence is still firmly against land surface of any magnitude between Australia and New Zealand during the Tertiary. The present average depth of the Lord Howe Rise is about 2,200 metres, and that of the Norfolk Ridge about 1,500 metres¹⁶, and despite the continental crust composition of these ridges, there is no evidence of an orogeny massive enough to bring about such a change in relief in that area in the Tertiary. In fact recently Houtz *et al.*²² reported sediments of Eocene age on the Lord Howe Rise, an indication that it has been a relatively deep submarine ridge since that time. This is not to say that the Tasman Sea ridges might not have been much shallower in the Mesozoic than today.

So the general picture that emerges of New Zealand during the Mesozoic is of a geosynclinal zone running NNW-SSE with respect to present true north, with significant land surface area that at times was either greater or less than the amount exposed today. The area presently occupied by the Chatham Islands was much closer to Antarctica than today; some exposed land probably occurred in their vicinity. Workers still differ on a number of points in reconstructions, the writer considers

the relative positions of the Tasman Sea submarine ridges in the Mesozoic and Tertiary to be of great importance. Workers are also at odds concerning the mechanism underlying continental dispersal, especially of the New Zealand Plateau block. Fleming¹⁸ tended to discount as too simple Wright's theory of small convection cells operating during the Cretaceous²⁴, to account for opening of the Tasman Sea. Nevertheless all the modern reconstructions place Australia, Tasmania, New Zealand and Antarctica considerably closer together in the early Tertiary and the Mesozoic than they are today.

The writer is not really competent to criticise the sea-floor spreading data and marine magnetic profiling results on which the recent models are based, but if one turns now from geological and geophysical data to faunal and floral distribution patterns, the balance of data from these sources tends to support the model of Griffiths and Varne rather than those proposed by Smith and Hallam, or Jones, with regard to the relative position of New Zealand.

NEW ZEALAND MESOZOIC BIOGEOGRAPHY

The volume and quality of geological and geophysical data from the southwest Pacific have greatly increased in recent years, but unfortunately the same is hardly true of Mesozoic terrestrial fossils. Only the New Zealand marine fossils have left a reasonably good record, and it is to these we must turn for most evidence of changes in composition of the fauna and flora during the Mesozoic, reflecting variation in availability of relatively shallow water dispersal routes.

Late Palaeozoic.

Fossils occur in the Lower New Zealand Trias which represent the last remains of an extensive and singularly enigmatic austral Permian fauna⁷. As Fleming pointed out, it is not possible at present to reconcile the presence of the circum-Pacific, non Tethyan trigoniid bivalves in the early New Zealand Trias and Permian with the usual conception of Gondwanaland. However if Smith and Hallam are roughly correct in their general assessment of the pre-drift relationship of Antarctica, South

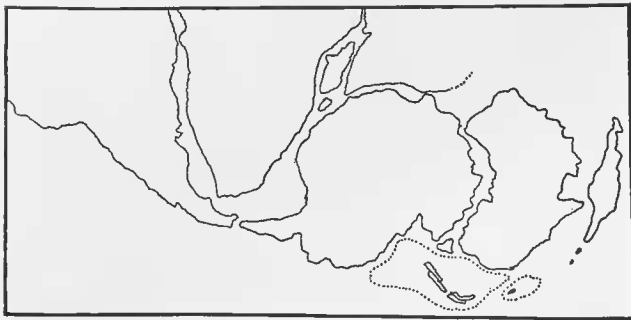


FIG. 2. — Probable pre-drift configuration of southern continents, modified from Smith and Hallam (1970), and Griffiths and Varne (1972).

America, and the Australian New Zealand region, then these continental areas shared in part a common continuous coastline that could have functioned as a major dispersal route. We do not know the extent, if any, of large marine embayments which might have allowed the penetration of marine taxa into regions we vaguely consider should lie well within the "coastline" of Gondwanaland. The Permian climate is generally considered to have been relatively severe, possibly the climate and sea temperature permitted some exchange between what are now boreal and anti-boreal zones, as happened again in the Pleistocene and perhaps early Quaternary. The close relationship evident between eastern Australian and New Zealand faunal successions in Ordovician and Permian strata do seem to suggest reasonably close proximity²⁴.

Triassic.

The early and mid-Mesozoic marine fossils have been reviewed by Marwick²⁵ and Fleming^{6, 7}. A number of forms were assumed to have had efficient dispersal by planktonic larvae; these species are found not only in New Zealand Trias but are widely distributed elsewhere. Existence of ammonite fossils with wide distribution suggests that some immigration to New Zealand was then possible, but in general during this period the fauna shows much generic endemism, as for example in the brachiopod group represented by *Mentzelioptis* and others. This group has been considered archaic and endemic²⁶, and is particularly prominent in the upper meso-Trias (local Ladinian sequence). The surface area of the shallow water zone around the emergent land of the early and pre-Mesozoic New Zealand Plateau was probably large enough to function as major evolutionary centre. Caughley²⁷ humorously but rightly reminded zoogeographers to beware of unconsciously assuming that taxa in a region under study always had to have migrated there from some outside point. The pelecypod fauna of the upper Trias is a mixture; regionally endemic groups include genera such as *Hokonius* and *Oretia*. Some of this group are common to both New Zealand and New Caledonia. More widespread genera include *Nuculana*, *Anodontophora* and *Palaeoneilo*. The pelecypod *Monotis* colonized this region during the mid-Upper Trias²⁸, but was replaced by beds of *Otapiria* in the Jurassic. Brachiopods of the Upper Trias continued to show strong endemism. Upper Triassic ammonites such as *Procydonautilis*, *Arcestes* and *Pinacoceras*, by contrast were all Tethyan. *Otapiria* is now also known from the North Pacific (Dr C. A. Fleming, *in litt.*).

Jurassic.

Sediments of definite non-marine origin are recorded in the Jurassic²⁹, and at least one writer believed land surface area to be greater in the vicinity of the New Zealand archipelago than it is today³⁰. Another reported that some exposed land probably existed to the west of present-day New Caledonia during the Permian — Upper Jurassic period³¹. Evidence from the molluscan fossil record strongly suggests that... "the New Zealand-New Caledonia region... isolated during the (Triassic-Liasic) downwarping of this Pacific margin"...³, was linked to the northwest during the Upper Jurassic Rangitata Orogeny by the establishment of... "some shallow-water dispersal avenues"...⁷. There is evidence that the New Zealand geosynclinal region was beginning to rise in the mid-Jurassic³². The Upper Jurassic fossils show virtually no endemism, implying that New Zealand shallow water zones were not isolated at this time. A study of terrestrial plant microfossils showed that some of the podocarps were in New Zealand during the Jurassic geosynclinal phase³³, and that their precursors may have been there much longer. Evidence from several sources thus shows the same general pattern. In one way or another, a land mass which approximates to present-day New Zealand was in a favourable situation to receive a large influx of immigrants during the mid-Upper Jurassic. That the exposed area of "Tasmanitis" might have been greater than that of the present New Zealand archipelago is acceptable. This would increase the statistical chances of successful reception of species crossing water gaps of greater or lesser magnitude. Nor is there necessity to assume that the shelf or land regions of this part of Gondwanaland were ever completely continuous with other areas. The disbarmonic fauna, including such examples as the frog genus *Leiopelma*, the reptile *Sphenodon*, the Apterygiformes and Dinornithiformes, and a great number of invertebrate forms, is adequately accounted for by just such discontinuities in the dispersal routes.

Although New Zealand and New Caledonia have enough biogeographical factors in common to justify their being grouped as a distinctive "Maorian" Province, each has its own unique (and apparently old) faunal elements. For example among the Carabidae (Coleoptera), flightless Scaritini occur in New Caledonia and flightless Broscini in New Zealand¹².

Cretaceous.

During the last era of the Mesozoic a number of factors seem to indicate changes in the configuration of the southwestern Pacific region of Gondwanaland. From the geological point of view it is difficult not to assume that the massive Rangitata Orogeny was not in some way related to the rifting process that eventually led to the dispersal of the present continental elements^{7, 18}. Vine and Hess⁴¹ suggested that such orogenic phases can pre-date actual rifting by about 20-25 million years. The climax of the orogeny occupied much of the Lower Cretaceous, and in the Upper Cretaceous we find a new and distinctive group of taxa with austral relationships appearing in the New Zealand and Antarctic marine fauna^{7, 42, 4}, suggesting that circum-polar Antarctic troughs were forming^{2, 7}. This austral element was new, and not related to the earlier enigmatic Permian one⁷. In addition, the Tethyan and cosmopolitan elements which dominated the New Zealand Mid and Upper Jurassic were again replaced by forms showing increasing endemism, another sign of progressive isolation and deepening waters around the archipelago.

The Endeavour Fracture Zone is widest south of New Zealand; the influx of austral faunal elements into the Upper Cretaceous seas of New Zealand supports the theory that the New Zealand Plateau region had begun to "northeast" prior to the separation of Australia and Antarctica in the Palaeocene-Eocene. Sedimentary studies show a deep marine transgression between those two continents by the Eocene, and Carey⁴⁵ considered that a "Red Sea-like" trough occupied the position of the Great Australian Bight even by the Upper Jurassic. Tasmania was probably effectively isolated by the beginning of the Eocene. Analysis of sediments also shows that a distinct Cretaceous marine transgression^{46, 47} followed the Jurassic one. The former was probably the beginning of a continuing trend, deepening through the early and mid-Tertiary. By the Oligocene the sediments west of Tasmania are clearly abyssal in nature². The "Tasmantis" — New Zealand area (and that west of New Caledonia, probably) was also subject to extensive marine invasion during the Cretaceous⁷. This was the beginning of a period of nearly complete isolation of the area, except from such taxa as could reach the archipelago by overwater dispersal and establish themselves. This isolation (and such dispersal) has continued throughout the Tertiary and the Quaternary periods.

The writer sees no requirement to change previous conclusions drawn concerning the trans-Antarctic dispersal of *Nothofagus* prior to the southern continents drifting apart^{5, 6, 48}. Anomalous distribution of *Nothofagus* species in New Guinea and New Caledonia is not a problem of Mesozoic biogeography. Cranwell⁴⁸ and the writer⁶ discussed possible solutions to this. In fact the new geophysical evidence provides an easier solution to the big part of the "Nothofagus Problem", i.e., the distribution of living and fossil members of the genus in Australia, Tasmania, New Zealand, Antarctica and South America, but not in Southern Africa. The time of separation of Africa from Antarctica is still somewhat imprecise, but the event probably occurred during the Upper Jurassic³⁰, and recently the more definite figure of 106 millions years ago has been mentioned⁹. This would then support the argument for the evolution and dispersal of *Nothofagus* across Gondwanaland during the Lower Cretaceous. Populations of *Nothofagus* are now very regionally specific, very poorly adapted for over-water dispersal, and are almost certainly not being successfully dispersed across water at the present time⁴⁹.

Jardine and McKenzie have re-examined the very interesting problem of the evolution and dispersal of marsupials with reference to continental drift⁹. Divergence of marsupials and the placentals probably occurred about 150-100 million years ago, perhaps from Jurassic eupantotheres^{50, 51}. The earliest known marsupial fossils are in North American Cretaceous strata; the European and Asian equivalents are perhaps yet to be found. Writers are not prepared to speculate on present limited evidence that North America was the evolutionary centre. Didelphoid marsupials appear

in European Palaeocene beds, and persist until the Miocene. The Palaeocene is also the time of first appearance in South America, presumably resulting from an invasion from North America at the very end of the Cretaceous⁵³. Since Africa appears to have separated from South America and Antarctica in the Upper Jurassic, South America-Antarctica seems the only possible source of marsupials for Australia, even though no fossil record is known from Antarctica as yet⁵. The highly specialized Australian marsupial fauna of about 170 living species, is thought to have evolved in isolation since Australia separated from Antarctica 40-45 million years ago. They appear to stem from a single ancestral stock. The earliest known fossil marsupials in Australia are in Oligocene beds⁵⁴. Coastal Antarctica had a cool temperate climate in the late Cretaceous and Palaeocene, and this did not become really severe until the mid-Tertiary⁵⁵.

There are still some unexplained factors in the history of Australian marsupials. For instance why did placental mammals not colonize the continent at about the same time as marsupials? Or did they reach it, fail to adapt, and rapidly become extinct? Jardine and McKenzie did not cite the papers of Jones, Carey and Smith and Hellam, and thus appear to ignore the difficulty of dispersal of marsupials from Antarctica to Australia if the Bight region had been transgressed by the sea quite early in the Cretaceous. This is especially important since they took pains to emphasise ("p. 24) that the marsupials are a group with limited powers and success in over-water dispersal. Nevertheless there were probably island chains and the problem is theoretically not insurmountable. The same authors further noted that in the Mesozoic the pattern of major groups of plant taxa was to have either a "Gondwana" — type distribution or a "Laurasian" type distribution. This segregation broke down in the Tertiary. For example after a Gondwana-restrictive distribution in the Mesozoic, *Podocarpus* spread along the Pacific margins during the Tertiary. None of the data and discussion of the authors seems to demand modification or rejection of foregoing conclusions on the Mesozoic of New Zealand.

SUMMARY OF PROBABLE MESOZOIC HISTORY OF NEW ZEALAND

The New Zealand fauna and flora show a striking degree of endemism. They are disharmonic, and many important Australian, South American and Indo-Pacific taxa are lacking or very poorly represented. There has clearly been much evolution and speciation during long periods of virtual or total geographical isolation. This is particularly true of the South Island, where the relatively large surface area and varied topography very probably have continuously provided more ecological niches than in the North Island^{45, 46}.

Providing the concepts of continental rifting and actual drift are not confused, new data from sea-floor spreading and application of tectonic plate theory to the area do not very appreciably alter the previously published picture of the New Zealand Mesozoic largely developed by Fleming^{5, 7, 8, 10}. In fact the fit between geological and biogeographical phenomena of the New Zealand region is improved. Judging from shared faunal sequences, relationships between New Zealand and southeastern Australia were apparently close in the Permian. The Lord Howe Rise and Norfolk Ridge may then, and no later, have formed a connecting region of dry land, or large exposed ridges close to one another and in turn to Australia and New Zealand. The presence of a strong austral element in the marine fauna of the New Zealand fauna might be explicable in terms of extensive marine embayments in the whole region, but the pre-Triassic configuration of the area is still enigmatic. Best evidence at present suggests the Norfolk Ridge in the Permian was a marine trough, part of the New Zealand Geosyncline (Dr. C. A. Fleming, in litt.).

The "Tasmantis" — New Zealand region appears to have been relatively isolated during the Triassic and Liassic. This isolation was much reduced during the Jurassic Rangitata Orogeny, and at this time the land surface area may have been greater than today. Between the Triassic and Tertiary continuous land connections (as opposed to shallow water zones) to Antarctica and Australia are still at best very doubtful concepts, despite the revised timetable for the disruption of the southwest Pacific region of Gondwanaland based on marine magnetic profiling. No Mesozoic reptiles so abun-

dant elsewhere appear to have reached New Zealand, except for *Sphenodon*. Snakes, and terrestrial mammals are almost totally absent. New Zealand's late Mesozoic and Tertiary isolation from both Australia and Antarctica apparently being sufficiently developed to prevent colonisation by marsupials or monotremes. Presumably Australia's immunity from placental invasions in the Tertiary permitted the survival and speciation of marsupials and the archaic monotremes. The Lord Howe Rise and the Norfolk Ridge may have partially contributed to "Tasmantis" in the Mesozoic, but it appears that they were completely submerged by the Eocene and probably as early as the Lower and mid-Cretaceous. During the later part of the Jurassic, or in the Lower Cretaceous, the whole New Zealand Plateau region began to move northeastwards with respect to Australia and Antarctica under the influence of sea-floor spreading. After separation of the crustal block the deep basin of the Tasman Sea formed progressively, and the original straight configuration of the southwest Pacific geosyncline became distorted by differential rifting within the block, its contact with the southern end in Antarctica was severed, and the Campbell Plateau and the Chatham Rise rotated to the positions they hold today, with coincident slipping on the New Zealand alpine fault of the order of 300 km. The dispersal of this block was followed by the Eocene separation of Australia from Antarctica, and northward movement of the former.

Present evidence does not support the idea of New Zealand forming part of the boundary of two tectonic plates⁸⁷.

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